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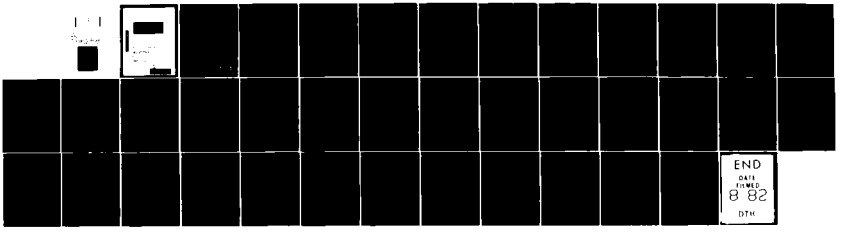

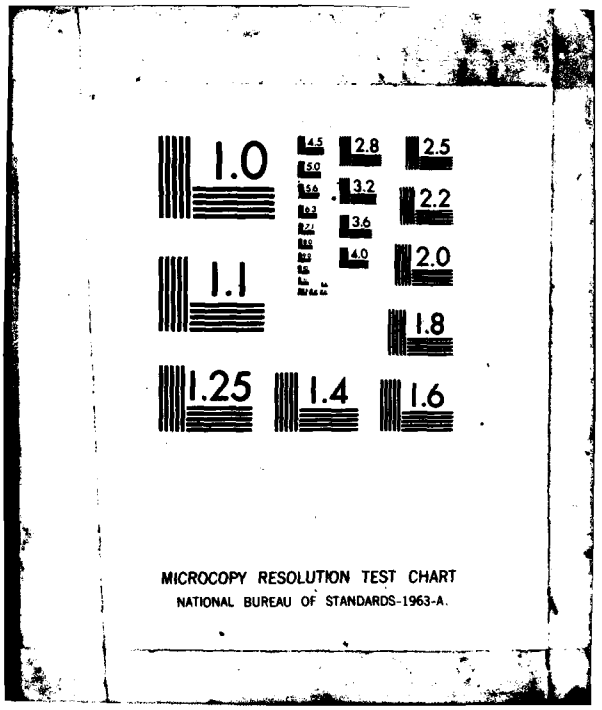
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The Future of Statistics as a Discipline

by

Ralph A. Bradley*

FSU Statistics Report No. M594

September, 1981

The Florida State University
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The Future of Statistics as a Discipline

Ralph A. Bradley*

I would not be here tonight except for the influence of one man, Professor Emeritus George L. Edgett of Queen's University, Canada. For many years he was the only teacher of statistics at his institution and he encouraged a remarkable number of undergraduate mathematics students to pursue advanced study of statistics. I was one of them. It was appropriate that he was elected a Fellow of this Association some years ago in recognition of his teaching.

I am here tonight also because of the example, encouragement and support of many friends in statistics as well as that of my wife and family. I would like to express my gratitude for the inspiration of all, particularly W. G. Cochran, Harold Hotelling, Gertrude Cox, P. L. Hsu, Boyd Harshbarger, H. O. Hartley and S. S. Wilks, not all of whom were my former teachers. The 1981 Wilks Memorial Medal has been awarded to Holbrook Working here tonight. Professor Cochran was a model for many of us of a distinguished statistician able to bring the tools of mathematics to bear on real problems of applied statistics. A special session in his memory will be held at this meeting.

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*Ralph A. Bradley is the Robert O. Lawton Distinguished Professor of Statistics, Florida State University, Tallahassee, FL 32306. This article is the text of his Presidential Address delivered at the 141st Annual Meeting of the American Statistical Association, August 11, 1981 in Detroit.

Presidential Addresses have changed through the years from technical presentations to discourses on selected aspects of our discipline and Association, perhaps to the relief of many members of the audience. I have heard nearly thirty of them and I reread some in preparation for this evening. The rereading may have been a mistake, leading to the impression that one can only reassemble a subset of a finite set of ideas into a new combination. Nevertheless, it is apparent that there is a resurgent undercurrent of concern for the fractionation of statistics into specialized disciplines, for widening gaps among them, and, after 142 successful years for the American Statistical Association, even for the identity of the discipline itself. My presentation centers on the preservation of the integrity of the discipline and future actions and activities that will permit us, individually as statisticians and collectively as the American Statistical Association, to continue to serve society.

STATISTICS AS A DISCIPLINE

Much has been written about statistics as a discipline, a science, and a profession — Good examples are the articles by Leslie Kish (1978) and H. O. Hartley (1980). All of us here would agree with these descriptions, but we would begin to disagree on elaborations, thus showing diversity of interest that can be both beneficial and divisive. Statistics has been called a mathematical science by some and an applied science by others.

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If statistics is a mathematical science, it stands alone as the one that postulates models for natural phenomena that must be subject to observation, verification, and refinement, the very process of scientific method. If statistics is an applied science, it differs from other applied sciences that utilize the theoretical discoveries of science in the production of new products that serve man. Statistics as an applied science is applied in the service of science itself; it serves as a tool in other scientific investigations. I believe that it is this role of statistics that attracts and generates the dedication of its practitioners.

We all see our discipline a little differently, depending on our talents, training and circumstances. Margaret Martin (1981) looks at statistics as product rather than method and sees statistics as

> ... The process of producing and summarizing large data sets for the use of others, the principal functions common to large government statistics bureaus ... it encompasses not only statistical methodology as a tool, but the whole gamut of activities that must be performed ... planning, collecting, analyzing, and disseminating data. The practice of many of these functions is not based primarily on statistical science or methodology but is an art, based on a mixture of intuition, experience, and judgment as well as scientific evidence or procedures.

Kish (1978) contrasted statistics with other sciences:

> Statistics is a peculiar kind of enterprise of contradictory character because it is at the same time so special and so general. Statistics

> exists *only* at the interface of chance and empirical data. ... The data of other scientists comes chiefly from their own disciplines. ... In stark contrast, statisticians have no field of their own from which to harvest their data. ... Because we have no field of data of our own we cannot work without others, but they also cannot do without us — or not very well, or for very long.

Hartley (1980) discussed the recognition of uncertainty in modern science and said:

> Statistics is part of this modern scientific outlook of uncertainty. Its theory can be appropriately described as "the mathematics of uncertainty." The deterministic world law from which all phenomena can be exactly predicted is abandoned.

Kish saw also the philosophical side of the discipline:

> In all her (his) endeavors the statistician cannot avoid the basic philosophical problem of empirical science: to make inferences from limited sets of empirical data to large finite populations and to infinite superpopulations of random variables induced by causal systems. ... A closer link between the disciplines of statistics and the philosophy of science, at least in joint seminars, would be stimulating to both.

P. C. Mahalanobis (1965) viewed statistics as a key technology in national development.

How do non-statisticians view statistics as a discipline? Can the answer be not at all or almost that? The July 4, 1980 issue of *Science*, a centennial issue*, contains articles ranging from Present and Future Frontiers of the Sciences to the Interaction of Science and Technology with Societal Problems. Statistics is not mentioned anywhere as a discipline.

There is an article in the centennial issue by Hugh J. Miser (1980) on operations research and systems analysis in

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*Science, Volume 209, Number 4452, July 4, 1980.

which he notes that a comprehensive study of an air quality issue could demand not only research analysts and meteorologists but also demographers, economists, statisticians, and others. Saunders MacLane (1980) writes on the present and future frontiers of Mathematics, but neither probability nor mathematical statistics is mentioned. Herbert A. Simon (1980) stresses the importance of good data collection methods and good data, gives L. J. Savage credit by reference but not by name for the concept of subjective expected utility, and devotes some space to game theory. One may infer that he gives social scientists credit for improved data collection. Articles on engineering, industrial research, food and nutrition, demography, energy, environment, and information resources mention computing, make no real references to statistics, but present data and refer to costs and benefits, assessment of risks, and threshold limits of toxicity.

Statistics is more involved in science than the centennial issue of *Science* suggests. The American Statistical Association has formed advisory committees upon requests from various agencies of the federal government: the Census Advisory Committee, the Ad Hoc Committee on Energy Statistics, the Ad Hoc Committee on Nuclear Regulatory Research, and the Committee on Statistics and the Environment*. One of my first actions as President was to appoint, on the request of the Bureau of the Census, a second committee led by Margaret Martin to advise the Bureau on technical aspects of the estimation and distribution of the undercount in the 1980 census.

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*For 1981 committee memberships, see *Amstat News*, Number 72, February, 1981.

Other committees of the ASA (associated with government statistics) contribute also; they are concerned with law and justice statistics, statistical standards, policies on federal statistical positions, small area statistics, privacy and confidentiality, and problems of incorrect polls and abuses of polls. Philip Handler, President of the National Academy of Sciences, has recommended the establishment of an Office of Science headed by a Chief Scientist in the Environmental Protection Agency and I have endorsed his recommendation. He stated that the Chief Scientist should have outstanding abilities in statistics, data management, quality assessment, scientific measurement, evaluation and usage. Members of the ASA represent our Association in many other organizations and on their committees. Our members individually support our discipline in science in diverse ways. It is a major strength of statistics that it is represented with dedication and even evangelical zeal.

What then is wrong with statistics and what should we do for its future?

The contributions of statisticians to science, in contrast with the philosophy of science, are secondary ones. We act as collaborators in the scientific enterprise. Hopefully, our role is a collegial one and we can contribute to investigations, usually conceived by others, from their planning stages to their definitive conclusions. Are we too willing to attempt salvage operations late in a project? How often is data analysis a salvage effort? Are we too servile? Let us be

scientists and not shoeclerks, as urged by Irwin D. J. Bross (1974). Does statistics as a discipline and do statisticians as individuals receive appropriate credit for their contributions? Several years ago a brochure on statistical consulting, stating abstractly the expectations of both the consultee and the consultant, was developed by the Statistical Consulting Center of the Florida State University. I proposed the title, Consulting Etiquette, which was not used. Such a brochure, setting forth abstractly policies on use of data, confidentiality, acknowledgments, authorships, and related matters, can be most helpful in providing a basis for easier decisions in special cases. My first recommendation is that

(i) The American Statistical Association develop a brochure on policies and procedures in statistical consulting in service to the discipline.

Required courses in statistics are among the most feared by graduate students from other disciplines. Yet, after successful completion of such courses and appointment to professional positions, a surprising number of these individuals confidently act not only as their own statisticians but as consultants and teachers of statistics to others. In a way visible to the public, we see non-statisticians discussing conclusions from invalid polls or performing as statistical experts in courts of law. The phenomenon seems peculiar to statistics — it seldom happens, for example, in mathematics. It is a phenomenon that can discredit statisticians. It is a phenomenon that leads some to see a need for a Code of Conduct for Statisticians, a step towards a licensing procedure. H. O. Hartley in his address said:

> We must convince colleagues in other areas that they would be wasting their time dabbling in statistics in an inept do-it-yourself extravaganza.
>
> And convince them we shall. For we shall not idly look on while our professional identity is being destroyed ...

Let me proceed to some of the means to the retention and enhancement of our professional identity. It is my belief that the future of statistics as a discipline depends not on regulation but on how we as statisticians plan for and perform in the future. Our future depends on the recruitment and training of talented young people, the quality and relevancy of our research, our unity as a profession, and our respect for each other amid diverse specializations. It depends greatly on the leadership and representation of the American Statistical Association. I consider these topics briefly in turn, make some recommendations, and challenge you to find solutions to other issues raised.

RECRUITMENT INTO THE DISCIPLINE

The long-run future of any discipline depends on its ability to attract and train the very best young people. The demand for statisticians remains strong in industry, government and education. Graduate enrollments in departments of statistics have decreased in the last several years, particularly of U.S. students and at the post-master's level. The future shortage of doctorates in statistics is only beginning to be

apparent because of the several years' lag inherent in the system. The shortage seems likely to reach a critical level in the very near future. The imbalance between demand and supply results from several simultaneous adverse circumstances and from continuing lack of appreciation of the challenges of the discipline.

There is general public disenchantment with science. Philip Handler (1980) commented:

> Some of our brightest young people now believe that the unanticipated consequences of technology have *already* injected the seeds of inevitable disaster into human affairs. They look askance upon the introduction of any new technology and are fearful, therefore, of further scientific advance.

Frederick Mosteller (1981) notes that a well-educated public is needed for support of the sciences and is concerned:

> In the United States we have seen an erosion in education in science and mathematics both in amount and quality. The citizen has become less well informed, as we know from the many studies of the National Assessment of Education Progress.

There are public misconceptions of science also. Handler discussed risk assessment in relation to energy policy and noted that the penalties of serious energy shortage are far greater than those associated with any available energy technology. The data of Table 1 from Niles Howard and Susan Antilla (1979) show activities ordered by resultant deaths with rankings of these activities on the basis of perceptions of risks of three population groups, the League of Women Voters, college students, and business and professional club members, perceptions apparently influenced by biases of the media and peer-group emotional reactions*.

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*Values of the Spearman rank correlation coefficient for the rankings of the three groups respectively in comparison with the list order are 0.527, 0.305 and 0.643. The coefficient of concordance for the rankings of the groups is 0.870.

1. Activities Ordered by Associated Deaths and Group Rankings of Perceived Risks

	Activity and Deaths per Year (Est'd)	Group Rankings of Perceived Risks* I	II	III
1.	Smoking (150,000)	4	3	4
2.	Alcoholic beverages (100,000)	6	7	5
3.	Motor Vehicles (50,000)	2	5	3
4.	Handguns (17,000)	3	2	1
5.	Electric power (14,000)	18	19	19
6.	Motorcycles (3,000)	5	6	2
7.	Swimming (3,000)	19	30	17
8.	Surgery (2,800)	10	11	9
9.	X-rays (2,300)	22	17	24
10.	Railroads (1,950)	24	23	20
11.	General (private) aviation (1,300)	7	15	11
12.	Large construction (1,000)	12	14	13
13.	Bicycles (1,000)	16	24	14
14.	Hunting (800)	13	18	10
15.	Home appliances (200)	29	27	27
16.	Fire fighting (195)	11	10	6
17.	Police work (160)	8	8	7
18.	Contraceptives (150)	20	9	22
19.	Commercial aviation (130)	17	16	18
20.	Nuclear power (100)	1	1	8
21.	Mountain climbing (30)	15	22	12
22.	Power mowers (24)	27	28	25
23.	High school and college football (23)	23	26	21
24.	Skiing (18)	21	25	16
25.	Vaccinations (10)	30	29	29
26.	Food coloring	26	20	30
27.	Food preservatives	25	12	28
28.	Pesticides	9	4	15
29.	Prescription antibiotics	28	21	26
30.	Spray cans	14	13	23

*The groups are I - League of Women Voters, II - College Students, III - Business and Professional Club members.

Career plans of students entering college are affected by public attitudes towards science and mathematics. There has been a marked decline in students entering the mathematical sciences and increased competition for the mathematically talented, most notably from computing science and business. In the Fifties, when employment opportunities in mathematics were limited, some of the best students turned to statistics; in the Seventies, when limited opportunities prevailed again, students have turned to computing science with its high demand and rewards. The situation is indicated by data on freshman plans as reported by Gail S. Young (1980) and on NSF graduate fellowships. Table 2a shows the ten-year decrease in percentages of freshmen planning to study mathematics and statistics in contrast with other fields, while Table 2b shows career plans in percentages for freshmen. The marked decline in NSF graduate fellowships awarded in probability and statistics in recent years is shown in Table 2c.

2. Freshman Study Plans and NSF Fellowship Awards

2a. Some Probable Fields of Study, by % of Freshman Planning That Field

Field	Women		Men	
	1969	1979	1969	1979
Biological Science	2.7	3.9	3.8	4.3
Business	12.5	23.1	19.1	25.1
Education	19.2	12.5	4.8	3.6
Engineering	0.4	2.5	18.0	19.2
Physical Science	1.0	1.8	3.6	3.9
Computer Science	—	1.4	—	2.1
Math./Stat.	3.8	0.6	3.3	0.7

2b. Career Plans for Entering Freshmen, Fall 1969 and 1979, by Percentage

Career	Women		Men	
	1969	1979	1969	1979
College teacher	0.8	0.2	1.3	0.3
Computer science	—	3.3	—	4.7
Homemaker (full-time)	—	0.4	—	0.0
Research Scientist	1.4	1.3	3.3	2.4
Statistician	—	0.1	—	0.1
Teacher (elementary)	19.3	7.0	1.0	0.5
Teacher (secondary)	17.2	3.0	9.9	2.1

2c. NSF Graduate Fellowship Awards in the Mathematical Sciences*

Specialization	1976	1978	1980
Computer Science	12	12	22
Analysis	13	7	6
Algebra, Number Theory	2	7	4
Applications	11	11	4
Topology	4	2	4
Geometry	2	1	2
Operations Research	2	2	2
Logic, Foundations	3	1	1
Statistics, Probability	7	6	1
Unspecified	1	2	0
Totals	57	51	46

*Source: CBMS *Newsletter*, 15, 35, 1980.

Career opportunities in modern statistics are not well understood either by the public or prospective students. Statistics is seen as a dreary and drab occupation involved

with data tabulation; its role in research in science and social policy is not recognized. Statistics is newsworthy when it is in trouble -- poor election prediction or perceived undercount of minorities in a census. The first course in statistics is often dull and badly taught. Britain leads in the introduction of statistics and probability in secondary education and has a new journal, *Teaching Statistics*, for teachers of statistics in the schools. We lag behind, although serious efforts are being made by our ASA-NCTM* Joint Committee on the Curriculum in Statistics and Probability. Unfortunately, in the past, most of us have regarded training in statistics largely as postgraduate training and relied on the recruitment of students from mathematics.

Some efforts on recruitment to the profession are being made. The not very active Committee of Presidents of Statistical Societies sponsors the reactivated Visiting Lecturer Program in Statistics and publication of the brochure, *Careers in Statistics*. The Committee on Minorities in Statistics and the Committee on Women in Statistics make some special recruitment efforts. Some Chapters of our Association have programs to stimulate student interest in statistics. Individual administrators of departments of statistics actively recruit students to statistics through program brochures and sometimes through visits to colleges and universities.

We must do more as an association and as individual statisticians. Recommendations (ii) to (vi) that follow should help:

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*The National Council of Teachers of Mathematics.

(ii) A greater effort must be made at the national and chapter levels to create an awareness of career opportunities. I challenge you to develop new ways of doing this.

(iii) Individual graduate programs in statistics should be more aggressive and active in student recruitment.

(iv) Teachers of statistics should provide better insights to statistics as a science in introductory courses, and actively seek prospective statistics majors.

(v) Graduate students in statistics must be sought, not only among undergraduate mathematics majors but from other undergraduate areas such as engineering, the physical sciences, biology and economics.

(vi) Statisticians in government and industry should develop programs for the identification and support of currently employed individuals with interest in and the capacity for graduate study of statistics.

The demand for statisticians continues. Projections have been made by the National Science Foundation on personnel needs to 1990*. The study indicates that the supply of scientists will be adequate except that there will be two fields with large deficits of people with bachelor's and master's degrees: the computer professions and statistics. In areas with deficits, inadequately trained people are likely to be hired. We must develop continuing education programs to assist these employees to become competent members of our profession, contributors rather than liabilities to statistics.

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*See *Amstat News*, Number 74, April, 1981, and *Science and Engineering Education for the 1980's and Beyond*, National Science Foundation, Publication 80-78, Washington, D.C.

TRAINING IN STATISTICS

A conference on the Teaching of Statistics and Statistical Consulting was held at the Ohio State University in November, 1980. The large attendance, the papers presented, the quality of the participants, and discussions that took place indicate the very great interest in the improvement of training in statistics. The need for balance between training in theory and applications was emphasized as was the need to provide students with experience in the analysis of real data sets and in statistical consulting. A proceedings volume* is in preparation and recommended to you.

Departments of statistics and mathematical statisticians have been charged with being too theoretical, divorced from the real problems of statistics, and interested only in training others in their own image -- almost a process of cloning. Kish stated:

> Our academic statisticians have been nurtured in a fantasyland that they mistook for normalcy. Departments concentrated on turning out academic Ph.D.'s, and imported others to fill the hungry pipelines.

But this is too harsh and, indeed, as I have noted, Kish saw the role of statistics in the foundations of the philosophy of science. The pipelines were hungry and some concentration on the training of academic statisticians was necessary to develop the training facilities necessary for the future. Not all of us were in the extreme right tail of

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Rustagi, J. S. and Wolfe, Douglas (editors), *Proceedings of the Ohio State University Conference on the Teaching of Statistics and Statistical Consulting*, New York: Academic Press, anticipated 1981.

George Box's bimodal, thin in the middle, distribution of statisticians. Box (1979) envisioned a scale with applied statisticians on the left and theoretical statisticians on the right and suggested:

> If, alternatively, we aimed at a central target, then we might achieve a single unimodal distribution. This would still, of course, allow diversity. We would have some highly theoretical people in one tail and some highly applied people in the other. But the majority, while having proper theoretical training, might also possess ability and experience in applying what they knew to the solutions of scientific problems.

University departments of statistics are beginning to take sight on Box's central target, but his desired unimodal distribution may be achievable only as a mixture of two or more distributions. Present departments of statistics seem likely to contribute a distribution of statisticians better located than before, but skewed to the right, properly so because many new insights are needed in the foundations of statistical inference. Balance will be achieved with the creation and merging of a second distribution of statisticians with a mode close to that of the first but skewed to the left.

The development of the right-skew distribution has received the most attention. Universities have done a passable job in the past in training statisticians for academia, industry, and some positions in government. We shall achieve the right-skew distribution if the following recommendations on training are adopted:

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(vii) Statisticians should be trained to be scientists.

(viii) Teachers of statistics should instill in their students an inquisitive scientific attitude and the concept of scientific integrity.

(ix) Students should be oriented to become professionals in an important viable profession.

(x) Training programs should contain a required central core of sound theoretical courses in probability and statistical inference.

(xi) Students should be motivated towards cooperative research through some training in an area of application of statistics and through statistical consulting.

(xii) Student skills in communication should be strengthened through consistent emphasis on good written and oral presentations in class assignments, seminars, and theses.

Let me elaborate only a little. Students can be oriented in science and statistics through an orientation course stressing the role of statistics in scientific inquiry and providing some history of the development of modern statistics. Further orientation results from historical references in individual courses, examples set by instructors, and participation in research projects while in graduate school. Students require a strong theoretical foundation in statistics and probability in order to understand the applicability of current statistical methodology, to provide a base for the formulation of innovative approaches to new applied problems, and to understand future new methodology as a means for growth in the discipline throughout their careers.

Returning to the bimodal distribution of statisticians, I think that the left-hand mode may be more to the left of the desired central target for the unimodal distribution than is the right-hand mode. Also, the desired left-skew component distribution of the unimodal mixture of distributions may be more difficult to develop than the right-skew one because it has received less attention and may itself represent a mixture of several populations. Our Section on Statistical Education has sponsored a report* on the training of statisticians for industry. I would like to suggest that they address also the issue of the training of statisticians for what Margaret Martin has called statistical practice in bureaucracies, perhaps with the help of other interested Sections and Subsections.

Let me share a few preliminary thoughts with you on the issue. The problem is acute and divides us. We hear complaints that mathematical statisticians use language and techniques that are incomprehensible to applied statisticians and that the *Journal of the American Statistical Association* is too theoretical and unreadable. The complaints are unacceptable, even though we differ only in degree in our reading difficulties and authors could make more effort to communicate. Mathematics is the language of research in statistics and we must improve our skills in this basic language.

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*"Preparing Statisticians for Careers in Industry, Report of the ASA Section on Statistical Education Committee on Training of Statisticians for Industry", *The American Statistician*, 34, 65-75, 1980.

If the left-skewed distribution is to have a mode near the desired target, it is essential that applied statisticians also have basic understanding of probability and statistical inference. This may be accomplished through improved training of students of applied statistics and through programs of continuing education and self-training for those already in the profession. It is not clear that present departments of statistics have the expertise for the necessary training. The answer may be in the development of interdisciplinary programs with departments of economics, demography, sociology, political science and public health in which the department of statistics provides the recommended central training in statistics and probability and on such necessary components of the programs as sampling theory.

Continuing education in statistics must and will receive more attention in the future. In February, 1981, the ASA Board of Directors approved a position for a full-time Director of Continuing Education and an appointment was made in June. We have made a successful start with short courses on specialized topics in statistics in association with our annual meetings and through an increasing number of conferences and symposia on special topics. I recommend that

(xiii) Priority should be given to short courses to provide training in basic theory for those who have not had the opportunity for such training before, courses ranging from necessary mathematics for statistics through master's level probability and statistics.

Some such courses should be sponsored by the ASA in parallel with our present annual meeting short courses. The development of other courses by university extension programs should be encouraged.

(xiv) We should develop reading lists in preparation for the recommended short courses and as alternatives to these courses, we should help mid-career statisticians in self-training.

The discipline of statistics will be strengthened and more unified if all of us learn more about the skills and activities of statisticians at the other end of our bimodal distribution. It can become unimodal with new training efforts and mutual respect.

RESEARCH IN STATISTICS

The relevance of its research to problems of the real world affects the future of any discipline. If real statistical problems are not addressed by statisticians, solutions will be attempted by others. If they are inept, serious costs could arise, public policy might be wrongly directed, and statistics could be discredited. If they are competent, new subdisciplines may arise in other areas leading to fractionalization of statistics.

My remarks on research will be largely directed towards relevancy. This does not mean that I dismiss research on the foundations of our discipline or investigation providing new insights on properties of known methodology — we must value both. Some examples of perceived problem areas will be given, but I shall not provide a list of research topics, referring you instead to the excellent article by John Tukey (1954).

That many of his topics are still pertinent today suggests that he possessed considerable insight and that insufficient attention has been given to some of his ideas.

J. W. Duncan and J. Durbin (1980) described the communications gap between theoreticians and practitioners of statistics as a "vicious gap" and went on to say:

> Theoreticians tend to do 'desk research'. They often draw their research problems from other theoreticians' research, not directly from the real world. While the academicians too often fail to enrich their instruction and research with real life problems, practitioners do not formulate and present their problems to those theoreticians who have the time, the know-how, and the resources to solve them.

P. C. Mahalanobis regarded mathematics as a tool of statistical theory and real problems as the motivation for new concepts:

> Pure mathematics is indispensable for supplying rigorous logical foundations and for exploring the limits and refinements of statistical theory but has never given it essentially new concepts or tools. New statistical concepts and methods have continually emerged only in dealing with observations in the world of reality.

Harold Hotelling (1940) made an early plea for the recognition of the discipline and saw statistical consulting as a source of research ideas.

We do have a relevancy problem in research in statistics. Why has it occurred? It is easier to extend or investigate another property of a known statistical methodology than to generate new ideas. Research statisticians have become increasingly isolated from areas of application.

New computer-related technologies have changed data collection in industrial production. Faculty members have been faced with 'publish or perish' policies resulting in a stream of minor papers and paper splitting. An increasing number of specializations in statistics has created specialty clubs with few members who review and accept each others papers for journals. (Should editors select both a specialist and a generalist as reviewers?) Too many applied statisticians use the work-load of statistical consulting as an excuse for failure to do research and also fail to recognize research problems or to pose them to others.

Frank Wilcoxon was a Florida State University faculty member from 1960 to 1965 after a distinguished career in both statistics and chemistry in research and development. He brought with him an array of problems in statistics that he had encountered in his applied work and, through his enthusiasm, soon had a number of us working on those problems. We experienced the stimulation that can be brought to research in statistics from statistical consulting and problems of the real world. Also, I consulted regularly for some years with Mavis Carroll and the General Foods Corporation and a number of my papers were motivated by this consulting.

Some academic statisticians receive sabbatical leaves. Such leaves give them the opportunity to gain insight into relevant research in statistics if taken with industry

or government. Industry and government would do well to consider a system of leaves for their employees in statistics to give them the opportunity for more research time on problems that they have identified and to interest academic statisticians in them. Exchange and fellowship programs could assist also and I should note that several fellowship programs with government are now managed by the American Statistical Association. Any system of leaves or exchanges between statisticians in applied work and academic statisticians can assist research in statistics and mutual understanding.

The following recommendations seem reasonable:

(xv) Academic statisticians should consider sabbatical leaves with industrial or governmental groups in statistics for the resulting research stimulation.

(xvi) Research and study leaves for applied statisticians to permit time for research and interaction with theoretical statisticians should be developed.

(xvii) Industry and government should provide more consulting opportunities for academic statisticians, since benefits would accrue not only from the short-term solution of statistical problems but also from the associated long-term research that would be stimulated.

(xviii) Statistical societies, employers of applied statisticians, and universities should do more to develop exchange and fellowship programs in statistics to promote research, mutual understanding, and improved professional qualifications.

There are other ways to stimulate statistical research on relevant problems. Papers on unsolved problems in specific areas of application could be solicited for national and regional meetings and possible publication in statistical journals. Duncan and Durbin suggest that journals have a section on practical problems faced by practitioners. Just as others have recommended the development of data banks, this leads to the recommendation that

(xix) A problem bank in statistics should be developed, possibly with the assistance of the Sections of the American Statistical Association.

Let me turn briefly from the relevance of research in statistics to the research itself. On the foundations of statistical inference, we continue to have diversity of opinions and doubts as to logical validities. For example, my colleague, D. Basu (1980), concludes that the Fisher randomization test is not logically viable. Controversies related to Bayesian inference and classical inference continue to exist. They need to be resolved constructively, perhaps through a generalized theory that may include both. George Box (1980) has made an initial effort at reconciliation. More consideration should be given to the use of new concepts of inference in applications. An example is the work of Bruce Hoadley (1981) on a new Bayesian approach to use of empirical Bayes methods in a quality measurement plan. Much needs to be done on the foundations of statistical inference. Cooperative effort, not controversy, will assist.

Let me conclude my thoughts on research in statistics with some questions that may affect research. I have emphasized statistics as a science and its role in science, as many statisticians tend to do, and only mentioned the role of statistics in social policy that should include business decisions as well as governmental ones. Statisticians tend to think of the design and analysis of an experiment as an entity in itself and not as a step in an iterative scientific process. Does this affect our views on statistical inference? Scientific method should include the exploration of data from an experiment for insights that can lead to new investigations. Does this affect our views on dependent statistical analyses and problems of multiplicities of analyses? Why has there been so much emphasis on diffuse priors in Bayesian inference and why have the concepts of decision theory been applied more to properties of estimators and mean square error losses than to policy decisions? Is it simply because priors and loss functions are difficult to define and required information is difficult to obtain and likely to be too subjective in real applications? Have we subverted these procedures from their intended purposes? Have we failed to understand that experimentation and statistical analyses only contribute part of the information that goes into decision making? Do current emphases on exploratory data analysis and robust estimation suggest that we should be giving more attention to good data collection?

THE UNIFICATION OF STATISTICS

Within the human race, groups form through common origins or interests. Perhaps it is indicative of man's insecurity that these groups attempt to enhance their welfare through establishment of superiority over competitive groups and a sense of elitism. Much of the trouble in the world originates in this way. To a limited degree it even happens in statistics. The belief that there are widening gaps between various and diverse categories of statisticians has led to concern for the future of the discipline.

We seek the welfare of the broad group of individuals labelled statistician and believe that this can best be achieved through unification of the various categories of statisticians through establishment and support of common interests in preservation of the discipline. We support the other sciences and we are not recommending elitism, although we do have a common sense of pride in the accomplishments of statistics.

The International Statistical Institute has addressed the unification of statistics through the reports of its Committee on the Integration of Statistics and its Committee on Future Directions, the first referenced to Duncan and Durbin and the second presented to the ISI General Assembly at its 42nd Session in Manila*. The American Statistical

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*_Report of the International Statistical Institute Committee on Future Directions_, October, 1979, International Statistical Institute, The Hague, Netherlands.

Association has been aware of the problem also, but has approached it less directly, but perhaps more constructively, in its report* of a conference on the transfer of methodology between academic and government statisticians. The report that I cited earlier on preparing statisticians for careers in industry contributes also to communication between two categories of statisticians. It does seem that statistical societies provide the major vehicle for unifying statistics and for strengthening the future of statistics as a discipline.

Our several statistical societies with overlapping memberships have developed to meet special interests. They serve the discipline, its members, and society as they contribute new methodology to statistics. They contribute to the fractionation of statistics as they seek identity and fail to cooperate on issues of consequence to the whole discipline. Some years ago, the Committee of Presidents of Statistical Societies (COPSS) was formed to facilitate joint activities. COPSS has sponsored the Visiting Lecturer Program in Statistics, some joint publications, and some special lectures. COPSS has, however, been weak and we support the efforts of John Flueck, the present Chairman of COPSS, towards its revitalization. The Constitution of the American Statistical Association provides for cooperating or associated societies. I have two recommendations:

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*_Report on the American Statistical Association Conference on Transfer of Methodology Between Academic and Government Statisticians_, March, 1978, American Statistical Association, Washington, D.C.

(xx) Associated or cooperating societies should be encouraged to cooperate with Sections of the ASA in the development of programs for regional and annual meetings, in publications, and generally in support of common interests.

(xxi) Associated or cooperating societies that have no special alignment with a Section of the ASA should be encouraged to contribute to the programs of our meetings and in such other ways as result in mutual benefit. Reciprocal participation should follow.

The Eastern and Western North American Regions of the Biometric Society cooperate with our Biometric and Biopharmaceutical Sections and provide a model for my first recommendation. It is my hope that the Institute of Mathematical Statistics may provide an example of the second. Perhaps Regions of IMS will arrange sessions on the theory of statistics at our Annual Meeting in those years when we do not meet together, thus filling a serious void in our program.

William G. Cochran (1954) spoke on the structure of the American Statistical Association following some experience with the new Constitution of 1948. The 1948 Constitution encouraged the formation of Sections and emphasized associated societies. It is interesting that Cochran noted plans for the formation of a fifth section, the Section on Statistics in the Physical and Engineering Sciences, a membership approaching 5,000 (now nearly 15,000), and saw the Association as a voluntary, scientific one. In 1981, we have

eight Sections and two Subsections, we have increased the number and variety of our publications, and we should see our Association clearly as both a scientific and a professional one.

Our Sections and our publications are major sources of our strength. Sections provide means of association and intellectual exchange with others with similar interests in statistics. Sections assure members of sessions at meetings where new ideas on topics in their area of specialization are presented. On occasion, some Sections sponsor special conferences on special topics. More of this should be done. Sections cooperate with associated societies and, from time to time, respond to public issues involving statistics or persuade the Association to do so.

Our Sections could also become a source of future weakness if their successful development leads to the formation of separate societies. The more specialized journals tend to be associated with the activities of separate sections — the planned new *Journal of Business and Economic Statistics* was proposed by the corresponding Section. The success of the Association has led to large Annual Meetings with competitive, concurrent sessions. This has yielded complaints from members who seem neither to wish to exercise selectivity nor to recognize the stimulation possible from across-section interchanges of ideas. There have been suggestions that Sections hold separate annual meetings, a very bad idea in my view and a threat to unity. We must work to preserve our present unity and to the further unification of statistics:

(xxii) Every effort should be made to improve the ASA Annual Meeting, reducing session competition through good scheduling, the use of poster sessions, and perhaps experimentation with video tapes, but preserving the rights of members to present contributed papers.*

(xxiii) Because of the size of the ASA Annual Meeting, Sections should not consider separate annual meetings but rather meet unserved needs of their members through their own special meetings, meetings with associated societies, and topic-oriented conferences.

(xxiv) The Journal of the American Statistical Association should remain our prestige journal, retaining the goal of publishing the very best articles on the theory, methods, and diverse applications of statistics.

(xxv) Other journals of the Association, dedicated to more specialized interests in statistics, should remain open to contributions from all and be subject to publication policies established by the ASA Board of Directors.

The American Statistical Association has always been interested in data collection in government, beginning at least as early as 1844 — Bradley (1981). This interest has broadened through the years to review of the statistical

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*H. O. Hartley, in what was one of the last of his many contributions to the ASA, prepared an informal report with recommendations for the improvement of the Annual Meeting, which is now in the hands of the Committee on Meetings.

adequacy of major research studies, governmental organization and use of statistics, and appointments to senior governmental positions in statistics. From time to time, the ASA has responded to public use or misuse of statistics and arranged for testimony before Congressional committees. The American Statistical Association is the only society with sufficiently broad interests and broad membership to enable it to speak for the discipline and exert influence on public policy. The future unity of the ASA is most important to the future of statistics in America.

CONCLUDING REMARKS

I shall not conclude with a detailed summary. I have discussed statistics as a discipline, how others see it, and some of our contributions. I have no fears for the future of statistics as a discipline if we retain our enthusiasms for the subject, continue to work together, and close the gaps that emerge from time to time between categories of statisticians. We must exert more effort to attracting good young people to the profession, the improvement of training with new continuing education programs, and research on both problems of the real world and the foundations of statistical inference. The American Statistical Association must provide much of the leadership and this

will occur through the ideas, leadership and service of its members. I hope that Sections, Chapters and Committees of the American Statistical Association will consider my recommendations and act on those with merit.

At one time the Florida State University had a Last Lecture Series. The idea was that one should pass on those important words of wisdom that one would wish to transmit if, indeed, it were one's last lecture. I did not follow that approach, but, instead, have attempted to share some thoughts that may benefit statistics and our Association. I may have followed the stated plan of Sir Claus Moser (1980) who, in the introduction to his Presidential Address to the Royal Statistical Society, said that he would exercise the privilege of Presidents and unburden himself of opinions and prejudices. In all of this, I have borrowed from the ideas of others and added but a few of my own.

Paddy is reported to have said at his hanging that it was remarkable how the thought of it tended to concentrate the mind. I hope that the thought of this speech had a similar effect on my mind and that I have not inspired a lynching.

Let me thank the Officers, Board, and members of the American Statistical Association for their support. The often mentioned, dedicated efforts of Fred Leone, Ed Bisgyer, Jean Smith and the Washington office staff make the American

Statistical Association what it is today. I wish to thank particularly our Past President and Chairman, Margaret E. Martin, for her staunch support and willingness to pinch-hit for me from time to time — she is a very great person. Finally, I am enjoying being your President this year and appreciate your confidence.

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